United States
Department of
Agriculture

Forest Service

Agricultural
Research Service

NA-TP-04-92

Aerial Application of Racemic Disparlure to Manage Low-level Populations of Gypsy Moth, 1989

Giles County, Virginia

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NORTHEASTERN AREA
State and Private Forestry

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Introduction

This report documents the use of aerially applied racemic disparlure as part of a larger, ongoing project to control an isolated infestation of gypsy moths in Giles County, Virginia. The mating disruption pilot project was a cooperative effort among the USDA Forest Service (Forest Pest Management, Appalachian Integrated Pest Management Project, and Jefferson National Forest); the USDA Animal and Plant Health Inspection Service, Plant Protection and Quarantine (APHIS-PPQ); the USDA Agricultural Research Service (ARS); and the Virginia Department of Agriculture and Consumer Services (VDACS).

Since the gypsy moth pheromone was first isolated, identified, and synthesized (Bierl and others 1970), there has been much optimism about its use both in surveying and controlling low-level populations of gypsy moth (Lymantria dispar). When racemic disparlure, a 50:50 mixture of the positive (+) and negative (-) enantiomers (Iwaki and others 1974), is used as a mating disruptant to control populations, its effectiveness seems to be inversely related to the density of the population (Webb and others 1988, 1990). Researchers obtained favorable results in studies with the disruption technique in populations of 25 or less egg masses per hectare (Webb and others 1990; Beroza 1976; Webb and others 1988; Cameron 1979; Plimmer and others 1982; Schwalbe and others 1983). However, because low-density populations of less than 124 egg masses per hectare are difficult to quantify (Schwalbe and others 1988), effectiveness of the mating disruption technique has not been conclusive.

The objective of permeating an area with racemic disparlure is to mask the pheromone plumes emitted by the calling females, disrupting male orientation to the female (Schwalbe and others 1988). Although the mechanism is not thoroughly understood, desensitization of chemoreceptors in the male antennae appears to prevent males from locating mates (Carde and others 1989). In other words, there is so much disparlure in the air that the male antennae are no longer stimulated. A calling female would have to emit significantly greater amounts of pheromone than the ambient, saturated air to stimulate a male's searching behavior and pheromone trail following. Because mating disruption is positively correlated with dose rate (Webb and others 1988; 1990), the highest rate that has been tested in aerial applications, 75 grams active ingredient [AI] per hectare, was used in the Giles County pilot project.

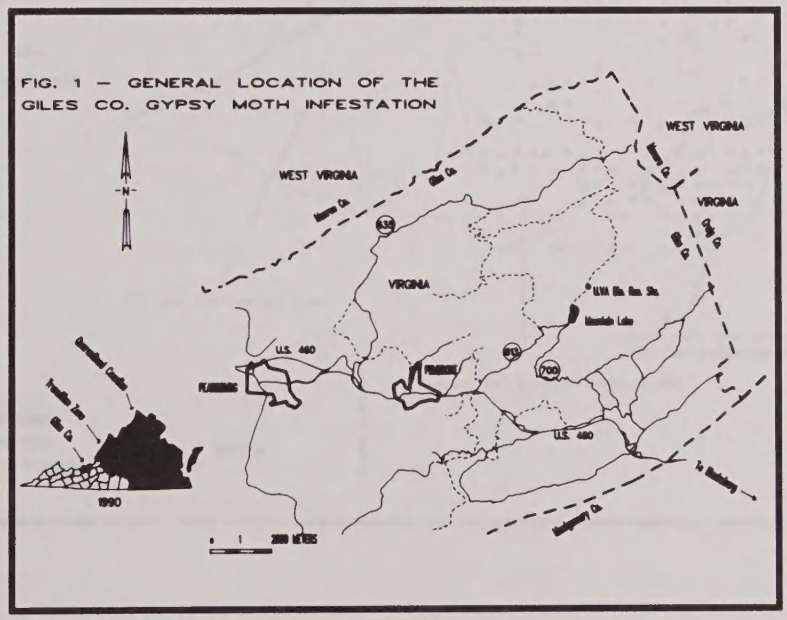
For mating disruption to be effective, the AI (racemic disparlure) must be formulated to release sufficient quantities for the entire 6-week mating period. Early studies have documented significant disruption of mating for all but the peak period of moth flight (Beroza and others 1974), which indicates that the ambient level of pheromone was sufficient to mask the calling females for all but the period of most intense mating activity. To prevent this problem, consistently higher dose rates have been used. However, the release profile of the applied dosage during moth flight and mating activity is also critical (Brooks 1979).

Because disparlure is volatile and is dispersed by air currents, complete coverage of the canopy is not as critical as it is with insecticides, which must come in contact with or be ingested by the insect. Racemic disparlure is denser than air. If the product is deposited near the forest floor, the concentration of pheromone, and consequently the effectiveness of the treatment, is likely to decrease proportionately with distance above ground (Kolodny-Hirsch and others 1990). Since mating may take place at any level in the forest, as evidenced by deposited egg masses, deposition of the disruptant was assessed in a forest canopy.

Because low-density populations (< 124 egg masses/hectare) are difficult to quantify, evaluations of mating disruption are based on indirect measurements of population, such as male trap catches or the mating success of monitor females deployed in the study areas. Although male trap catches indicate the absence or presence of this pest, particularly in isolated infestations, the number of moths trapped has not been directly correlated to egg masses per acre. Furthermore, in the years when pheromone has been applied, reduced trap catches only indicate that mating communication has been disrupted, not that mating has been sufficiently disrupted to suppress the population. Therefore, a combination of male moth trapping for 2 years after treatment and the incidence of mating in monitor females were used to evaluate efficacy in the absence of direct measures of populations in Giles County.

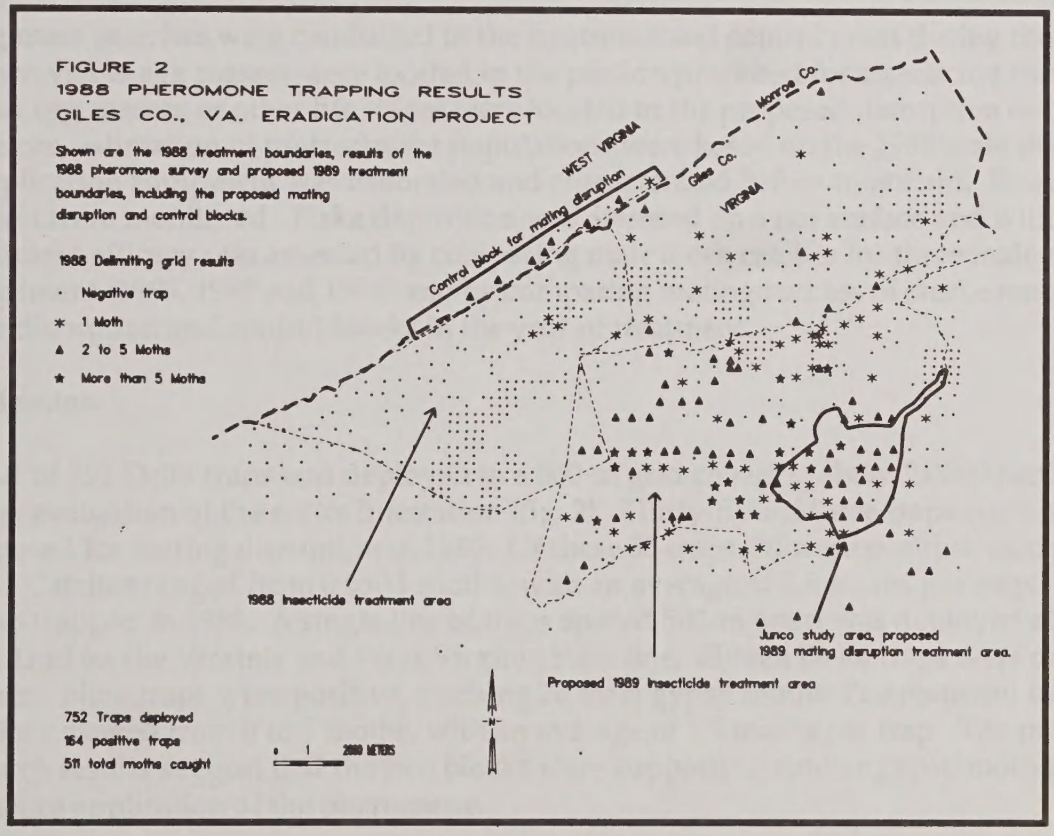
History of the Infestation

Surveys are conducted annually with pheromone-baited traps to locate isolated infestations or to follow



the rate of spread of the gypsy moth. It was through this type of survey that the infestation in Giles County, Virginia, was discovered, and plans were made for the 1988 and 1989 treatments. Figure 1 shows the general project area and the infestation in Giles County in 1989 relative to the advancing front of gypsy moth populations.

In 1985, a single male gypsy moth was caught in Giles County in one of the Delta traps deployed as part of the annual detection grid (3-km spacing). In 1986, a total of 11 moths was caught in 2 Delta traps. Trapping was intensified in 1987, and 222 moths were caught in 155 Delta traps. In the fall of 1987, three viable egg masses were found in the vicinity of the highest trap catches. Based on the 1987 male trap catches and egg mass surveys, about 5,060 hectares of the Jefferson National Forest and private lands within Giles County were treated with Bacillus thuringiensis (Bt) or diflubenzuron (Dimilin 25W) in the spring of 1988. Following the 1988 treatment, an extensive delimiting grid of 752 Delta traps (500-m spacing) covering about 24,000 hectares was installed within and adjacent to the 1988 treatment area (fig. 2). Results indicated that the 1988 treatment was successful in reducing gypsy moth populations within the area treated. However, the infestation had extended farther eastward than was previously documented and would require additional treatment in 1989. Two viable egg masses were found in the vicinity of highest trap catches in the fall of 1988.



While conducting the environmental analysis, it was discovered that an ongoing National Science Foundation study on behavior of the dark eyed junco (Junco hyemalis hyemalis) was located within the 7,406 hectare area proposed for treatment in 1989. Because a major part of this bird's diet consists of lepidopteran larvae, the application of either Bt or diflubenzuron would have adversely impacted the study. A decision was made to treat 1,032 hectares surrounding the junco study area with a gypsy moth-specific material (aerial application of racemic disparlure to disrupt mating); and to treat the remaining 6,374 hectares north and west of the disruption area with conventional insecticides in May 1989 (fig. 2).

Methods and Materials

The mating disruption project was carried out during late July 1989 in forest types highly susceptible to gypsy moth. The project area lies within the Ridge and Valley Physiographic Region, which is characterized by long, parallel ridges oriented in a northeast to southwest direction. The majority of the area is uninhabited forest land, ranging in elevation from 1,000 to 1,300 meters above sea level. The overstory vegetation is primarily oaks, with hemlock along the drainages. Understory vegetation is dominated by mountain laurel, rhododendron, striped maple, American chestnut, and herbaceous plants. The disruption area consists of a single block of 1,032 hectares, roughly round in shape. The area selected as a control block is a narrow strip of land two ridges to the northwest of the disruption block along the Appalachian Trail on the Virginia and West Virginia State line (fig. 2). The control block was the only area available with a similar gypsy moth population that was untreated in 1988 and that would remain untreated in 1989.

Intensive egg mass searches were conducted in the treatment and control areas during the late fall of 1988. Only two viable egg masses were located in the portion proposed for insecticide treatment in 1989. No other egg masses or other life stages were located in the proposed disruption or control blocks. Therefore, estimation of pretreatment populations were based on the 1988 male moth catch data. The application equipment was calibrated and characterized before treatment. Release rates of the formulation were monitored. Flake deposition was assessed on a flat surface and within a forest canopy. Treatment efficacy was assessed by comparing male moth catches for three male moth flights following treatment (1989, 1990 and 1991) and by comparing mating success of sterile females deployed in the disruption and control blocks in the year of treatment.

Efficacy Evaluation

In 1988, a total of 752 Delta traps was deployed in a 500-m grid covering about 24,000 hectares as part of the ongoing evaluation of the entire infestation (fig. 2). Thirty-five of these traps were in the 1,032 hectares proposed for mating disruption in 1989. Of these 35 traps, 30 were positive, catching 97 male gypsy moths. Catches ranged from 0 to 11 moths, with an average of 2.8 moths per trap. The control block was also trapped in 1988. A single line of traps spaced 500-m apart was deployed along the Appalachian Trail on the Virginia and West Virginia State line. Fifteen Delta traps were deployed in the control area. Nine traps were positive, catching 28 male gypsy moths. Pretreatment trap catches in the control block ranged from 0 to 5 moths, with an average of 1.9 moths per trap. The pretreatment (1988) trap catch results suggest that the two blocks were supporting similar gypsy moth populations in the year before application of the pheromone.

Standard APHIS, milk-carton-style traps were used to monitor the capture of male moths in the year of treatment (1989) as they are comparable in effectiveness (detection of low-level populations) to the Delta trap and require a greater number of accumulated male moths prior to affecting trap collection efficiency. Traps were deployed on a 250-m grid spacing in the control and the disruption areas. The traps in both blocks were checked on July 17, 1989, to confirm that moth flight had not started before pheromone application. Some of the traps were checked twice weekly from July 30, 1989, to August 15, 1989, during deployment of monitor females. After August 15, the traps were not checked until retrieval during the week of September 5, 1989. Because of problems with milk carton traps manufacturing, Delta traps were once again used for monitoring in 1990 and 1991. The disruption block was

trapped using a 250-m grid spacing, while the control block was trapped using a 500-m grid spacing.

Monitor females for evaluation of mating success in the year of treatment (1989) were supplied by USDA APHIS (Otis Air National Guard Base, MA). To comply with Federal and State quarantine regulations, lab-reared, F1-10K sterile females were used in this project. F1-10K females were the progeny of a male parent that was irradiated (dose = 10 krads) as a pupa. When mated with a normal male, these sterile females produce an egg mass that embryonates, but their eggs do not hatch. If these sterile females do not mate, an egg mass can be produced but will not embryonate. Lab tests indicate that these sterile females may be somewhat less competitive than wild females in attracting mates (Mastro, pers. comm.). Virgin, 1-day-old females were placed, untethered, in mating stations consisting of Delta traps containing no stickum; rather, a piece of burlap was stapled to the inside of the trap to provide a substrate for the female to grasp. Traps were assembled as usual, except the ends were not folded in. The mating stations were hung at selected points 1.5 m above the ground on the boles of trees separated from one another and from any pheromone traps by at least 50 m. Station locations were selected close to the highest multiple trap catches from 1988. One hundred stations were set up in the disruption block and 50 in the control block. Monitor females were deployed at all 150 stations twice weekly on Mondays and Thursdays for 3 weeks coinciding with peak moth flight (July 30 to August 20). They were left overnight and retrieved the next day. All females and eggs found were returned to the lab. The females were kept until they laid an egg mass or died. All eggs were examined for embryonation after 40 days.

Formulation and Application Equipment

The pheromone formulation used for mating disruption was Disrupt II (Hercon Environmental Co., Emigsville, PA), a controlled-release formulation consisting of 3-layered, laminated plastic flakes, about .8mm X 2.4mm. A sticker (Gelva RA 1990, Monsanto Corp., St. Louis, MO) was mixed with the flakes in approximately a 1:2 volume ratio, to ensure that the flakes would adhere to the leaves during application. The formulation was applied aerially by a Cessna 206 at a rate of 75 g AI per hectare from wing pods designed by Schwitzer Aircraft to deliver the Hercon flaked pheromone product. Each wing pod consists of two hoppers, one for flakes and one for sticker (fig. 3). The delivery rate of the flakes is controlled by an auger, while the flow rate of the sticker is controlled by a pump and tubing system. The flakes and sticker are mixed in a chamber just before dispersal through a spinner. Two pods are used during application, one mounted on each wing of the aircraft. The pods were field tested and calibrated at the APHIS Aircraft and Equipment Operations Center in Edinberg, TX, during

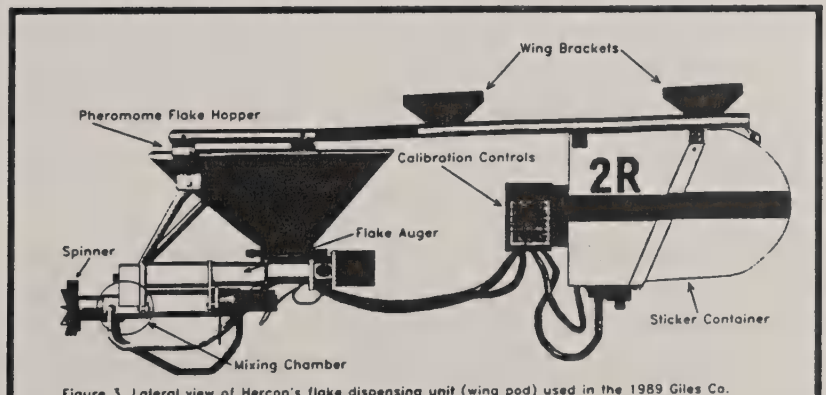


Figure 3. Lateral view of Hercon's flake dispensing unit (wing pod) used in the 1989 Giles Co. pheromone application.

April 1989 and again just before application in July 1989. The aircraft and pilot employed for calibration trials and operational spraying were provided by USDA, APHIS-PPQ.

During the April calibration trials, the wing pods were incapable of delivering a sufficient flow rate of flakes to yield an application of 75 g AI per hectare in one pass of the aircraft with the standard formulation of Disrupt II, containing 15.32 percent AI. The augers that control the flow rate of the flakes bind at higher RPM's and limit the amount of flakes that can be dispensed per unit of time. To achieve the desired dose rate, while not exceeding the maximum RPM of the augers, four variables can be altered: aircraft speed, lane separation, numbers of applications, and the percent of AI in the product. The minimum, safe air speed for the mountainous project area was set at 193 kilometers per hour (120 mph). Preliminary characterization trials indicated that a lane separation of 13.7 to 15.2 meters (45 to 50 feet) provided the best coverage. With aircraft speed and lane separation set for safety and coverage considerations, the desired dose rate could be achieved by either covering every acre twice or by increasing the percent AI of the product. A decision was made to use a new formulation of Disrupt II, containing 18.5 percent AI and limit the application to one pass with the aircraft.

Just before application in July, several trials were conducted at the airport to characterize the flake deposits across one swath, with the 18.5 percent AI formulation of Disrupt II. Three rows of roofing paper (each row 1- X 44-meters) were laid 30 meters apart, perpendicular to the flight path of the plane. After one pass of the plane, deposited flakes were counted in every 1-X 1.5-meter section of the three rows of roofing paper. Average deposition across the swath was computed for each trial by averaging the flake counts from the three rows. Further problems with the binding of the auger motors forced us to set the lane separation to 13.7 meters rather than 15.2 meters to consistently achieve the desired rate of 75 g AI per hectare. After determining that the equipment was functioning properly and consistently, treatment of the disruption block began. Application started on July 18, 1989, and was completed July 21. Twenty-one flights to the block were required, each trip covering a maximum of 51 hectares.

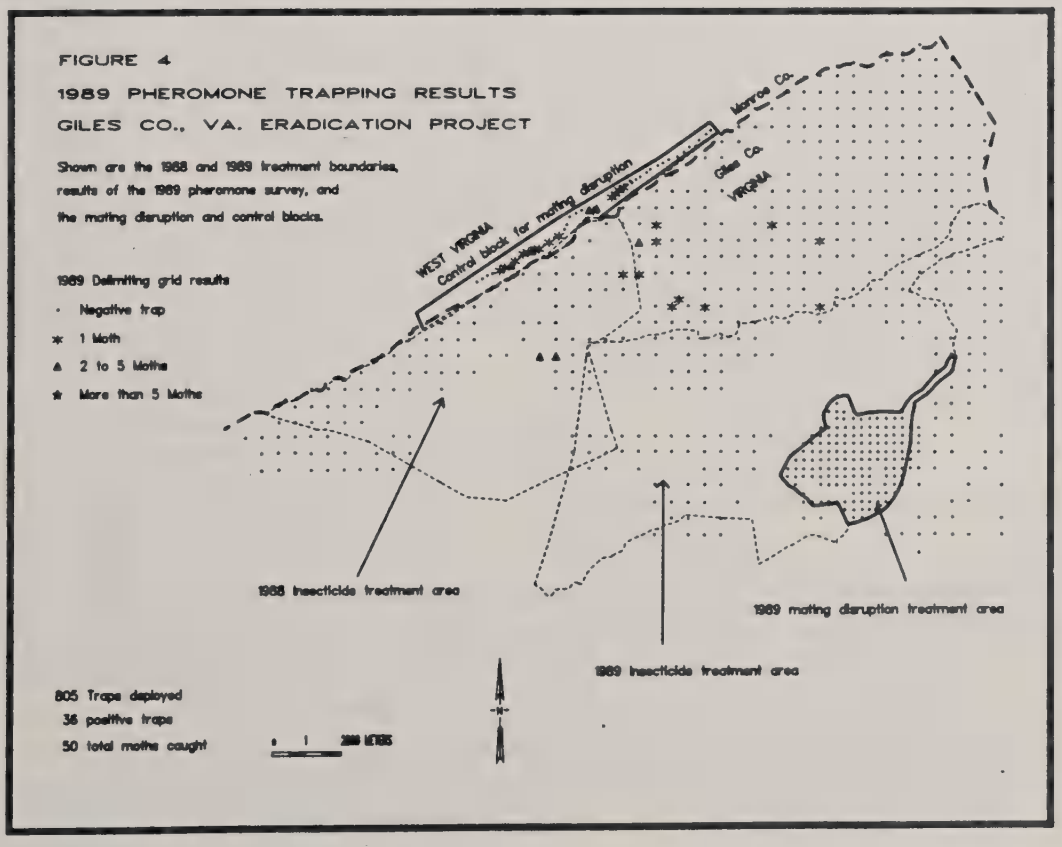
Release Rate Analysis

Upon receipt of the Disrupt II (June 29, 1989) and again at the start of application (July 18, 1989), flake samples were analyzed to determine initial racemic disparlure content. Samples of 20 flakes each were also collected from within the block at intervals over an 8-week exposure period and analyzed for residual disparlure content. Samples were collected on days 1, 5, 7, 11, 19, 28, 32, 41, 47, and 56 after spraying. For ease of collection, the flake samples were collected from 1- X 1-meter sections of roofing paper overflown during operational spraying and hung from limbs in the forest understory for aging. All flake samples were placed in glass vials for extraction with 2 ml of hexane. The extract was then analyzed by gas chromatography (GC) to measure the residual disparlure content.

Operational Deposition

Calculations based on mg AI per unit area of the Disrupt II predicted average deposits of 406,000 flakes per hectare (41 flakes per m2). To assess deposition achieved on a flat surface during operational spraying, a 1- X 144-meter length of roofing paper was deployed in an open area of the disruption block during application. The aircraft sprayed the roofing paper on eight parallel passes, each pass 13.7 meters apart.

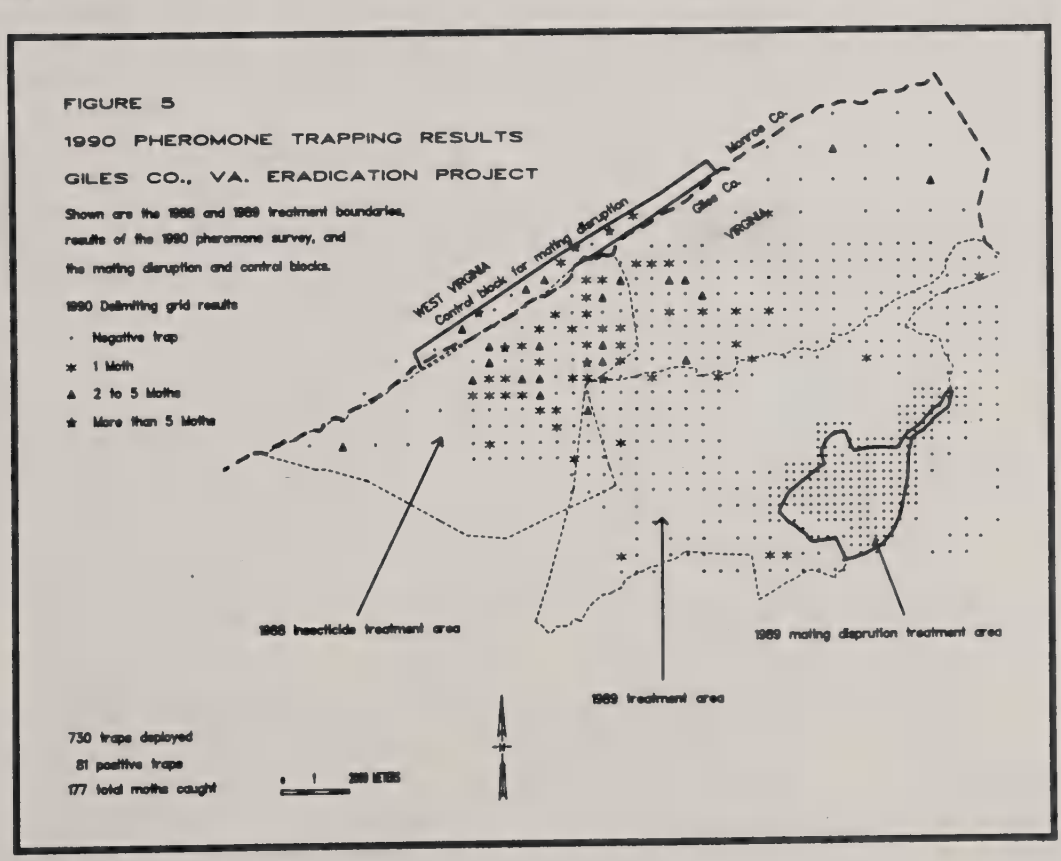
To assess deposition within a forest canopy, a 10X application of flakes (1X Disrupt II and 9X placebo flakes with 0 percent AI) was made to a 4-hectare study site within the disruption block. Twenty overstory and 20 understory trees were sampled. In the 20 overstory trees, 2 sampling points were established within each of 3 crown levels—upper (15 to 17 meter), middle (12 to 14 meter), and lower (6 to 9 meter). The 20 understory trees were sampled at one height only (1.5 to 3 meter), with 2 sampling points in each tree. In all, 160 sampling points, 40 at each of 4 canopy levels, were established and tagged before application. Each tagged sample consisted of about 100 leaves on one limb with leaf counts beginning at the terminal end. Overstory sampling was done with a Hi-Ranger aerial lift truck. During the week after application (July 25-29), all tagged limbs were revisited and the following information recorded: numbers of leaves, numbers of flakes, tag height (meters above ground), and percent crown cover above the tagged limb. Deposited flakes were circled with indelible markers. Foliage samples were taken from each sample tree and average leaf area for each species sampled was computed (northern red oak, white oak, red maple, American beech, striped maple, American chestnut, silverbell, and witch hazel). Samples were photocopied and leaf area was measured with an electronic planimeter. All tagged limbs were revisited on August 1-3 (11-13 days after spraying) and again on September 12-14 (53-55 days after spraying) to evaluate sticker performance and deposition over time.



Forty ground deposit sampling nets, consisting of 1 m^2 of parachute material in an inverted pyramid shape and suspended between trees just above the ground level, were deployed on a grid pattern within the 4 hectare, 10X block before application. These samplers were checked twice weekly beginning at application and continuing through September 12, 1989.

Efficacy

Pretreatment (1988) moth catches averaged 2.8 moths per trap in the Disrupt II block and 1.9 moths per trap in the control area. After treatment, the 170 milk-carton-style traps deployed in the disruption area captured 0 moths, while the 46 milk carton traps deployed in the control captured 21 moths. Table 1 shows the male trapping results before and after treatment. The 1989 trapping results are illustrated in figure 4.



The quality in construction of the milk carton traps produced for the 1989 season was disappointing. The hoods often slid down past the openings on the trap bodies or fell off entirely. Exactly how this may have affected the trap catches is unknown, but certainly the overall trapping efficiency was reduced. Even under these circumstances, the traps in the control area averaged 0.5 moths per trap, while the disruption area averaged 0.0 moths per trap, indicating the continued presence of a population in the control area and disruption of mating communication in the Disrupt II block. Based on the absence or low numbers of moths captured, egg mass surveys were not conducted in 1989.

In view of the poor performance of the milk-carton-style traps deployed in 1989, Delta traps were employed for the 1990 and 1991 surveys. Results of the 1990 post treatment grid trapping program are displayed in figure 5 and Table 1. As in 1989, zero moths were captured in the disruption area, while 52 moths were caught in the control area. Trap catches in the control block ranged from 0 to 19 moths, with an average of 4 moths caught per trap. Male moth captures suggest not only that the control area was still infested but also that portions of the 1988 and 1989 insecticide-treated areas were being reinfested. The disruption area, which is further southeast of the control block, continued to be completely free of catches 2 moth flights after treatment. However, in 1991, 1 male moth was captured in the disruption area in a trap deployed on the northwest edge of the treatment area. The remaining 169 traps deployed in the disruption area were negative. The 22 traps deployed in the control block continued to catch increasing numbers of moths in 1991. A total of 73 moths was captured in 16 traps.

Table 1—Male moth trapping results: 1988 (pretreatment), 1989 (year of treatment) and 1990 and 1991 (after treatment).

		Disruption Block			*Control Block*		
Year	*Trap type*	*Traps*	*Positive traps*	*Moths*	*Traps*	*Positive traps*	*Moths*
		Number			*Number*		
1988	Delta	35	30	97	15	9	28
1989	MC[1]	170	0	0	50	13	21
1990	Delta	170	0	0	13	8	52
1991	Delta	170	1	1	22	16	73

[1]Milk-carton-style trap

Results of deployment of sterile, monitor females to document mating success in the year of treatment were inconclusive (Table 2). Moth flight began on August 2 and continued until late August. Monitor females were deployed starting July 30, and the last batch of females was retrieved on August 15. Due to the timing of eclosion of the sterile, lab-reared females, deployment was terminated before the end of moth flight. Of the 530 females deployed, more than 85 percent were retrieved. Although 31 percent of the females retrieved from the treatment and control blocks produced eggs (singly or in a mass), none of the eggs embryonated after a 40-day holding period. Thus, none of the monitor females was mated in either block. In the absence of mating occurrence, the success of the project can only be determined by male moth catches.

Application Equipment

Results of the six trials conducted at the airport prior to the start of application are displayed in figures 6 and 7. The flow rate of flakes was affected by problems associated with the wing pods. In

Table 2. —Dates and numbers of monitor females deployed, retrieved, producing eggs and percent mating success at each deployment.

	Disruption Block				*Control Block*			
	# of females		*# of*	*%*	*# of females*		*# of*	*%*
Date	*deployed*	*retrieved*	*eggs*	*mated*	*deployed*	*retrieved*	*eggs*	*mated*
7/31	100	85	8	0	40	33	17	0
8/3	100	76	45	0	50	45	10	0
8/7	84	79	15	0	50	48	13	0
8/10	35	31	1	0	20	19	0	0
8/14	30	26	20	0	20	18	13	0
Totals	**350**	**297**	**89**	**0**	**180**	**163**	**53**	**0**

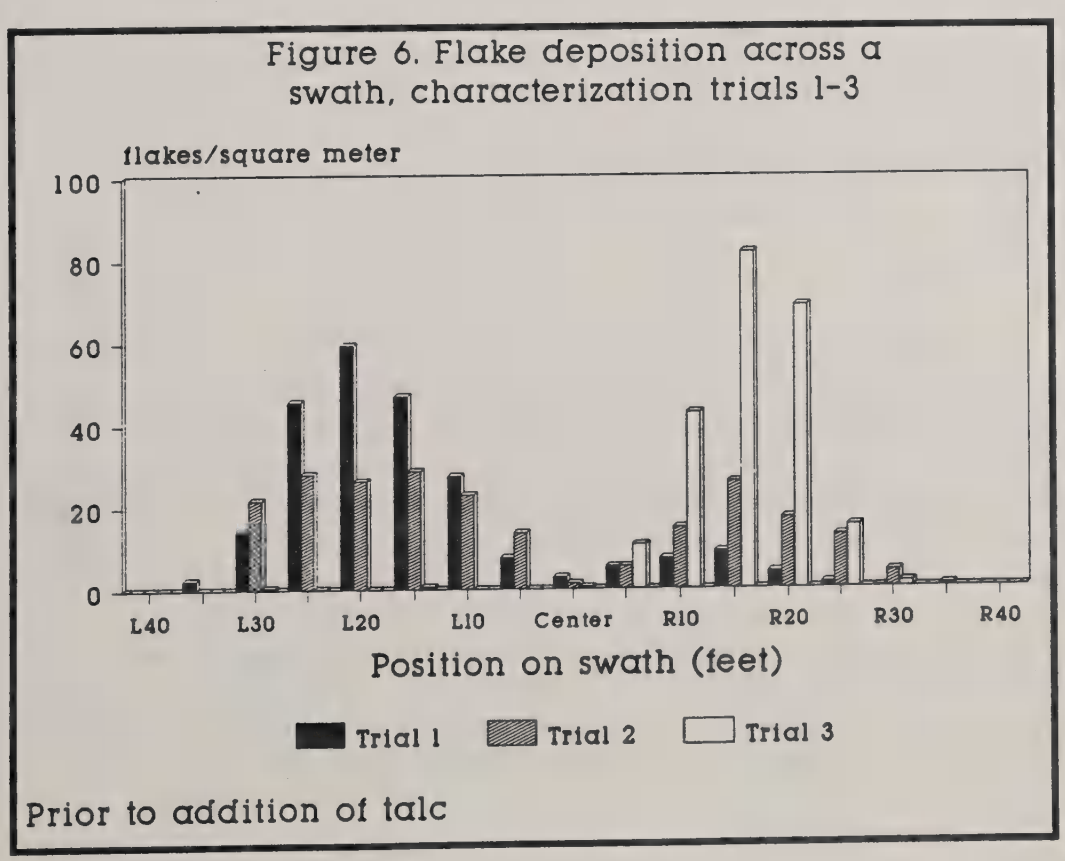
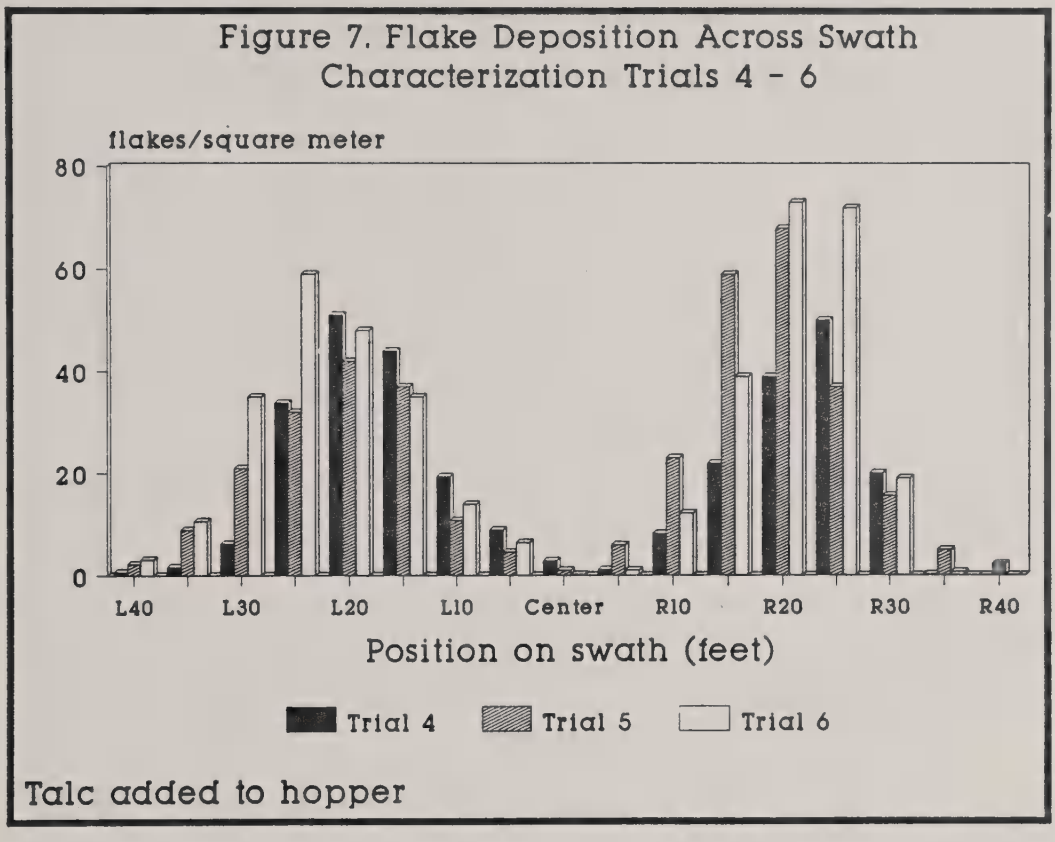


Figure 6. Flake deposition across a swath, characterization trials 1-3

Prior to addition of talc



the first three trials (fig. 6), flow rate varied significantly between the right and left wing pods within a trial, as well as between the trials, due to the flakes clinging together, or bridging in the hoppers. Delivery was improved when talc was added to the flakes (1 g talc/12 g flakes) before being loaded in the hopper. Figure 7 illustrates the typical deposition pattern achieved in trials 4-6 with talc added. The pattern within the swath was uneven, with peaks consistently occurring directly under the pods and valleys under the fuselage and wing tips, but more consistent between trials.

Release Rate Analysis

Results of GC analysis indicated that the flakes initially contained 17 percent racemic disparlure by weight, rather than the 18.5 percent indicated by the manufacturer. The achieved dosage was, therefore, 68.9 g AI per hectare instead of the 75 g AI per hectare planned. Moth flight began on August 2 (13 days after application) and continued through late August. The flakes retrieved from 1- X 1-meter sections of roofing paper released more than 80 percent of their total racemic disparlure content over a 56-day field exposure period. Sixty-five percent of the pheromone was released before moth flight in the first 11 days after application. Based on the analysis of the flake samples, only 10 percent of the AI was released during moth flight, and an additional 12 percent was released after moth flight was completed. Concerns over the rapid initial release rate of the product led to speculation that the sampling surface (roofing paper) may have affected the rate. Therefore, on October 11 (83 days after application), two additional flake samples (20 flakes each) were collected; one sample from the foliage and one from the roofing paper. The sample collected from foliage contained about twice as much

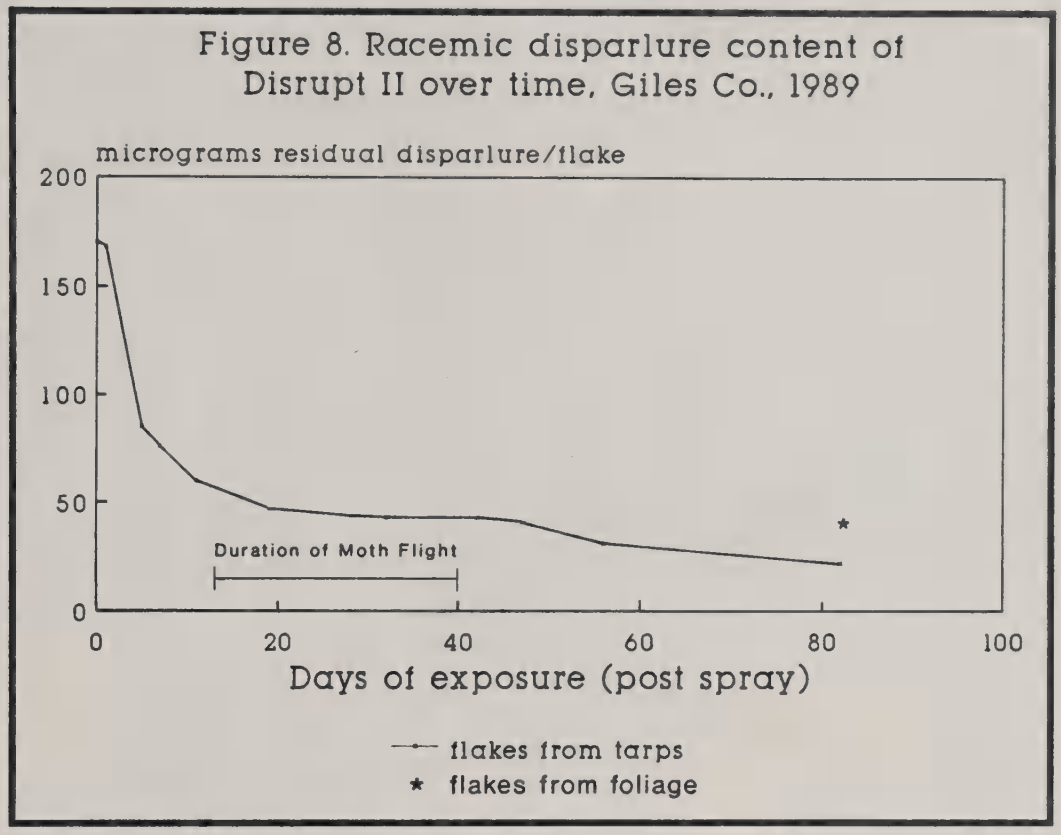


Figure 8. Racemic disparlure content of Disrupt II over time, Giles Co., 1989

residual disparlure as the sample collected from the roofing paper (fig. 8). The apparent accelerated loss of lure from flakes on the roofing paper may have been caused by the absorbed heat of the black surface of the roofing paper.

Operational Deposition

The deposition in an open area inside the treatment block during operational spraying averaged 41.2 flakes per m2 + 25.96 (x + SD) over the length of the 110-meter (360-foot) length of roofing paper (fig. 9). This compared favorably with our calculations of probable deposits of 41 flakes per m2 based on flake size and AI per unit area of Disrupt II. Although there is substantial variation in deposition across the 110-meter length of roofing paper, there are only six points where measured deposits are less than half of the average.

In the 10X deposition block, a total of 4,821 flakes was inventoried—3,202 flakes were found on 14,391 leaves at 160 sampling points in the canopy, and 1,619 flakes were found in the 40 ground deposit sampling nets. At application, about 25 percent and 28 percent of the flakes were intercepted by the upper and middle canopies, respectively, while 25 percent and 12 percent of the flakes penetrated to the lower canopy or understory (fig. 10). Ten percent of the flakes penetrated all levels of foliage and were deposited on the forest floor at application. Excellent performance of the sticker was demonstrated over the 6-week observation period; the upper, middle, and lower canopies lost only 2.1, 2.3, and 0.7 percent of their flake deposits, while the understory lost 0 percent.

Figure 9. Disrupt II Flake Deposition
8 Passes with a 45 foot lane separation

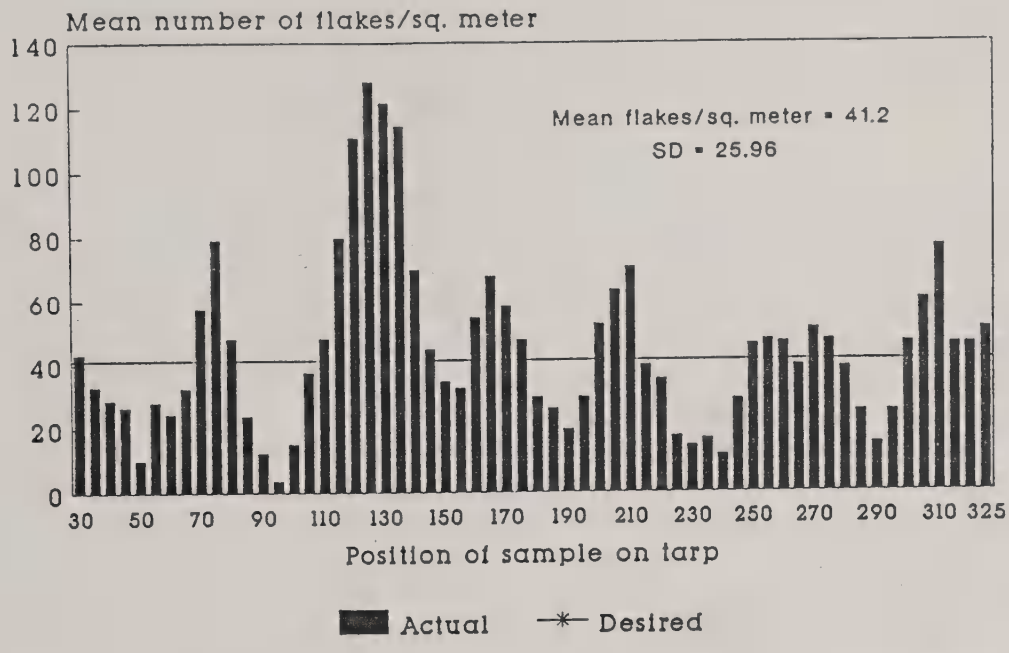
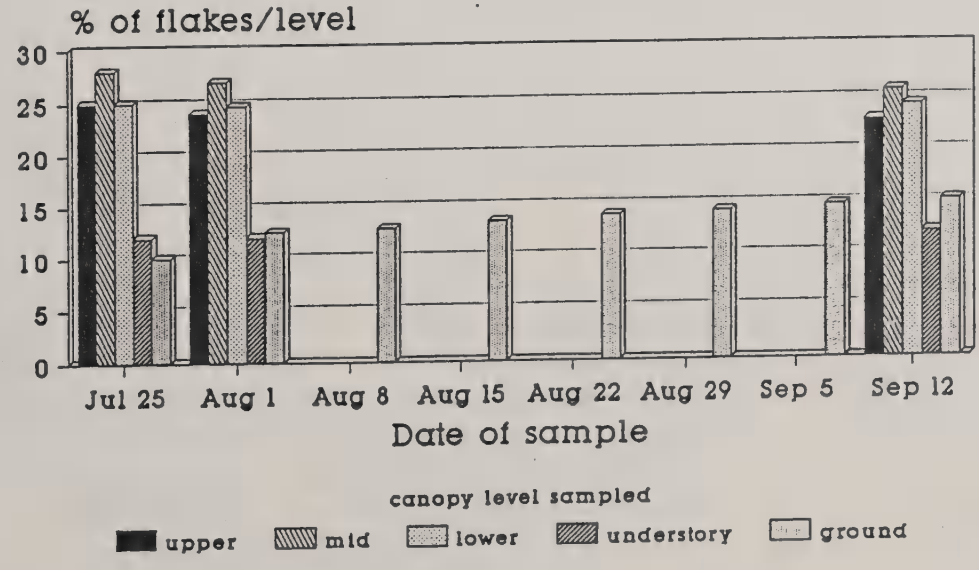


Figure 10. Flake deposition in the canopy, 10X Disrupt II block
Giles Co., Virginia, 1989



Ground nets sampled on all dates; canopy sampled only on 7/25, 8/1, and 9/12.

Average deposits per square meter of leaf surface at each canopy level sampled show that deposition was significantly lower in the understory (P=.05) (Table 3). There were no significant differences between deposits in the upper, middle, and lower canopy levels. In general, there was more variation in deposits within a level than between levels. Numbers of flakes deposited per unit area is weakly correlated with crown cover above the sampling point for all deposits, but only significantly correlated with crown cover in the mid crown level (r = .49, P = .0013).

The relationship between crown cover and deposition was confirmed in the ground deposit sampling nets in the 10X block (r = .49, P = .0014). At application, 1,619 flakes were captured in the 40 nets. Average catch was 40.25 + 26.61 flakes per m^2 (each net = 1 m^2). Since the calculated and observed deposition on a flat surface in the 1X area is 41.2 flakes per m^2, a deposition of 412 flakes per m^2 would be expected in a 10X area. Therefore, the flakes penetrating to the nets at application represent about 10 percent of the total applied. Of the flakes deposited in the nets at application, more than 94 percent were sufficiently covered in sticker to adhere to the nets on impact, 3.5 percent did not have sufficient sticker coverage to adhere to the nets and 1.1 percent were attached to debris that had fallen out of the canopy. In the 6 weeks after application, an additional 889 flakes were found in the nets. They represent an additional 5.4 percent of the total flakes applied and correspond well with the net loss of 5.1 percent of the flakes from the tree tops documented over the same time period. Of the 889 flakes accumulated in the nets after spraying, approximately one-third were still sticky and attached to leaves or twigs, while two-thirds were loose in the bottom of the nets, indicating that the sticker had weathered and was no longer functional.

Table 3. — The mean flake deposits in 4 levels of the canopy.

Level	*n*	*mean sample ht*	*mean deposits/ m2 leaf area*	*SD*	*mean crown cover (%) above sample point*
Upper	40	50'	55.6	22.6	2
Mid	40	39'	61.0	37.3	28
Lower	40	28'	55.3	41.1	51
Understory	40	5'	25.5	28.4	59

Conclusion

Although mating disruption was never actually documented, trapping results after treatment indicate that the block treated with Disrupt II was no longer supporting a detectable population. The fact that males were not captured in the traps in the year of treatment indicates only disruption of mating communication, but the fact that no moths were trapped in the disrupt area in the year after treatment and only 1 moth in the second year post treatment, strongly supports the conclusion that mating was disrupted. In contrast, increasing numbers of moths continue to be trapped in the control block. The deposition pattern of flakes achieved with the wing pods was documented, both on a flat surface and in a forest canopy. Deposition of flakes across a swath was highly variable but consistent between swaths. The initial distribution of the Disrupt II flakes throughout canopy levels was good, and the sticker performed well in keeping the flakes where deposited for the duration of moth flight. Results

of GC analysis of the initial lure content of the flakes indicate the achieved dose was 68.9 g AI per hectare rather than the planned 75 g AI per hectare. Although the release profile of the Disrupt II was monitored over time, it remains to be determined if the documented loss of lure from flakes aged on roofing paper is what happens to flakes aged on foliage. Therefore, no conclusion can be drawn about the total lure emitted during moth flight and mating activity. Future collections should be taken from foliage in treated areas to determine reliable release profiles of any products tested.

We were unable to document suppression of mating with sterile, lab-reared females as monitors. The existing population may have been too sparse to permit mating success at the level sampled. Also, quarantine restrictions limited us to use of F1-10K sterile lab reared females, which are somewhat less competitive in attracting mates. Considering the labor and associated costs required to deploy monitor females, future evaluations in areas with extremely low populations should not employ monitor females if only F1-10K sterile, lab-reared females can be used.

Based on the results of this project, additional field trials are in progress. Small, replicated plots have been established in areas with sparse populations (< 25 egg masses/hectare) along the leading edge of gypsy moth populations in Virginia. Efficacy evaluations include the use of specially designed escape-resistant mating stations that preclude the use of sterile females as monitors. Disrupt II and AgriSense polymeric beads, two formulations of controlled-release disparlure, are being evaluated. The beads offer a distinct application advantage over the flakes because they can be delivered through a conventional spray system with hydraulic nozzles.

Literature Cited

Beroza, Morton. 1976. Prospects for controlling some other insects. Journal of Forestry. 74: 146-150.

Beroza, M.; Hood, C.S.; Trefrey, D. [and others]. 1974. Large field trial with microencapsulated sex pheromone to prevent mating of the gypsy moth. Journal of Economic Entomology. 67: 569-664.

Bierl, B.A.; Beroza, M.; Collier, C.W. 1970. Potent sex attractant of the gypsy moth: its isolation, identification, and synthesis. Science. 170: 87-89.

Brooks, T.W. 1979. Controlled-release systems. In: Roelofs, Wendell L., ed. Establishing efficacy of sex attractants and disruptants for insect control. Entomological Society of America: 10-12.

Cameron, E.A. 1979. Disparlure and its role in gypsy moth population manipulation. Bull. Soc. Entomol. Suisse 52: 333-342.

Carde, R.T.; Willis, M.A.; Charlton, R.E. 1989. Mate finding behaviors and chemical communication in the Lymantriidae. In: Proceedings, Lymantriidae: a comparison of features of new and old world tussock moth; Gen. Tech. Rep. NE-123. Broomall, PA: USDA Forest Service, Northeastern Forest Experiment Station: 113-141.

Iwaki, S.; Marumo, S.; Saito, T.; [and others]. 1974. Synthesis and activity of optically active disparlure. Journal of American Chemical Society. 96: 7842-7844.

Kolodny-Hirsch, Douglas M.; Webb, Ralph E.; Olsen, Richard, Venables, Lee. 1990. Mating disruption of gypsy moth (Lepidoptera: Lymantriidae) following repeated ground application of racemic disparlure. Journal of Economic Entomology. 83(5): 1972-1976.

Plimmer, Jack R.; Leonhardt, B.A.; Webb, R.E.; Schwalbe, C.P. 1982. Management of the gypsy moth with its sex attractant pheromone. In: B.A. Leonhardt and M. Beroza, eds. Insect pheromone technology: chemistry and applications. Washington, DC: American Chemical Society: 231-242.

Schwalbe, Charles P.; Mastro, Victor C. 1988. Gypsy moth mating disruption: dosage effects. Journal of Chemical Ecology. 14(2): 581-588.

Schwalbe, Charles P.; Paszek, E.C.; Bierl-Leonhardt, B.A.; Plimmer, J.R. 1983. Disruption of gypsy moth (Lepidoptera: Lymantriidae) mating with disparlure. Journal of Economic Entomology. 76(4): 841-844.

Webb, Ralph E.; Tatman, Kathleen M.; Leonhardt, Barbara A. [and others]. 1988. Effect of aerial application of racemic disparlure on trap catch and female mating success of gypsy moth (Lepidoptera: Lymantriidae). Journal of Economic Entomology. 81(1): 268-273.

Webb, R.E.; Leonhardt, B.A.; Plimmer, J.R. [and others]. 1990. Effect of racemic disparlure released from grids of plastic ropes on mating success of gypsy moth (Lepidoptera: Lymantriidae) as influenced by dose and population density. Journal of Economic Entomology. 83(3): 909-916.

Footnotes

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